Neuromagnetic signals associated with translation of English words into Japanese words

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1 Introduction

Translation of English word into Japanese word requires several processes in the brain; detecting the word, reading the word, understanding the meaning, retrieving the Japanese word of the same meaning, and speaking the Japanese word. The third and fourth processes, namely “understanding the meaning” and “retrieving the equivalent Japanese word”, are essential to the translation.

To see these essential processes in the brain, we compared the magnetic responses to translating English words with those to reading English names.

2 Materials and methods

2.1 Subjects, stimuli and tasks

We studied 9 healthy Japanese student volunteers (all right handed; 3 females; 20-24 years old). The stimuli were 110 typical English surnames and first names (5.5±0.14 letters in average) in Experiment 1 and 138 fundamental English verb words (4.7±0.11 letters in average) in Experiment 2. These verb words are learned in the middle school in Japan. In each experiment, these stimuli were randomly selected and presented one at a time for 1.0 s on a fixation point of the screen situated 45 cm in front of the subject’s eye. This task-related stimulus was followed by an imperative stimulus after a 0.5 s blank screen. The subject’s task was to speak the English name in Experiment 1 and the Japanese word equivalent to the presented English verb word in Experiment 2, as soon and correctly as possible after the cessation of a 0.5 s imperative stimulus presentation. The experimenters checked whether or not the subject's answer was correct so that only the responses with the correct answer were averaged.

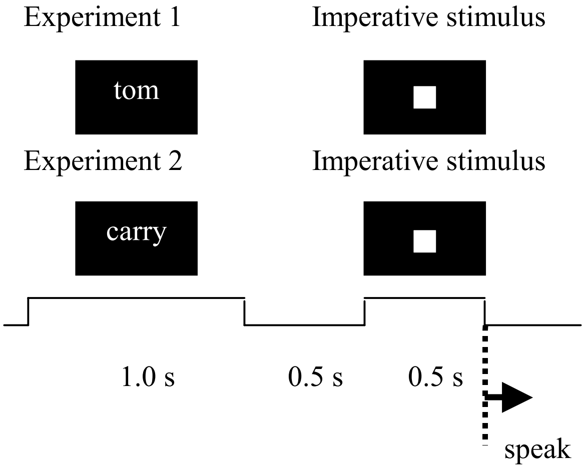

Figure 1: *Time chart for stimulus sequence. The first stimulus was an English name in Experiment 1 or an English verb word in Experiment 2, which was presented for 1.0 s. The second stimulus was a small white square, which was an imperative stimulus, presented for 0.5 s after the 0.5 s blank screen. The subject answered by speaking the name in Experiment 1 and the translated Japanese word in Experiment 2 after the imperative stimulus disappeared.*

2.2 Recording and analysis

We recorded the magnetic responses by a whole scalp neuromagnetometer (Neuromag-122^{TM}, Neuromag, Ltd., Finland) in a four-layered magnetically shielded room (MSR4B, Amuneal Corp., USA).

The signals were first analog-filtered between 0.03 and 100 Hz and then digitized at 0.5 kHz. An epoch either with a vertical or horizontal electrooculogram (EOG) exceeding 150 µV, or with an MEG signal beyond 3000 fT/cm was rejected. The magnetic signals averaged more than 80 epochs were digitally lowpass-filtered at 40 Hz. The DC-offset during the baseline from -0.1 to 0 s was removed. The analysis time was extended from -0.1 s to 1.5 s.

Equivalent current dipoles (ECDs) were estimated by the revised local channel method assuming the single dipole in a spherical head model [2].

The active regions shown by ECD clusters obtained in Experiment 1 were subtracted from those in Experiment 2 to obtain the regions activated mainly in Experiment 2, which were considered to be related to translation. In this subtraction, we eliminated the ECD clusters obtained in Experiment 2, that were located closely to those obtained in Experiment 1. Thus, the subtraction result included ECD clusters obtained in Experiment 2 that were far from those obtained in Experiment 1. We estimated the activity of 28 cerebral regions of interest by calculating the active latency length of the subtracted ECD clusters. In each of 28 brain regions, we performed Student's t-test to obtain the regions significantly activated by the translation.

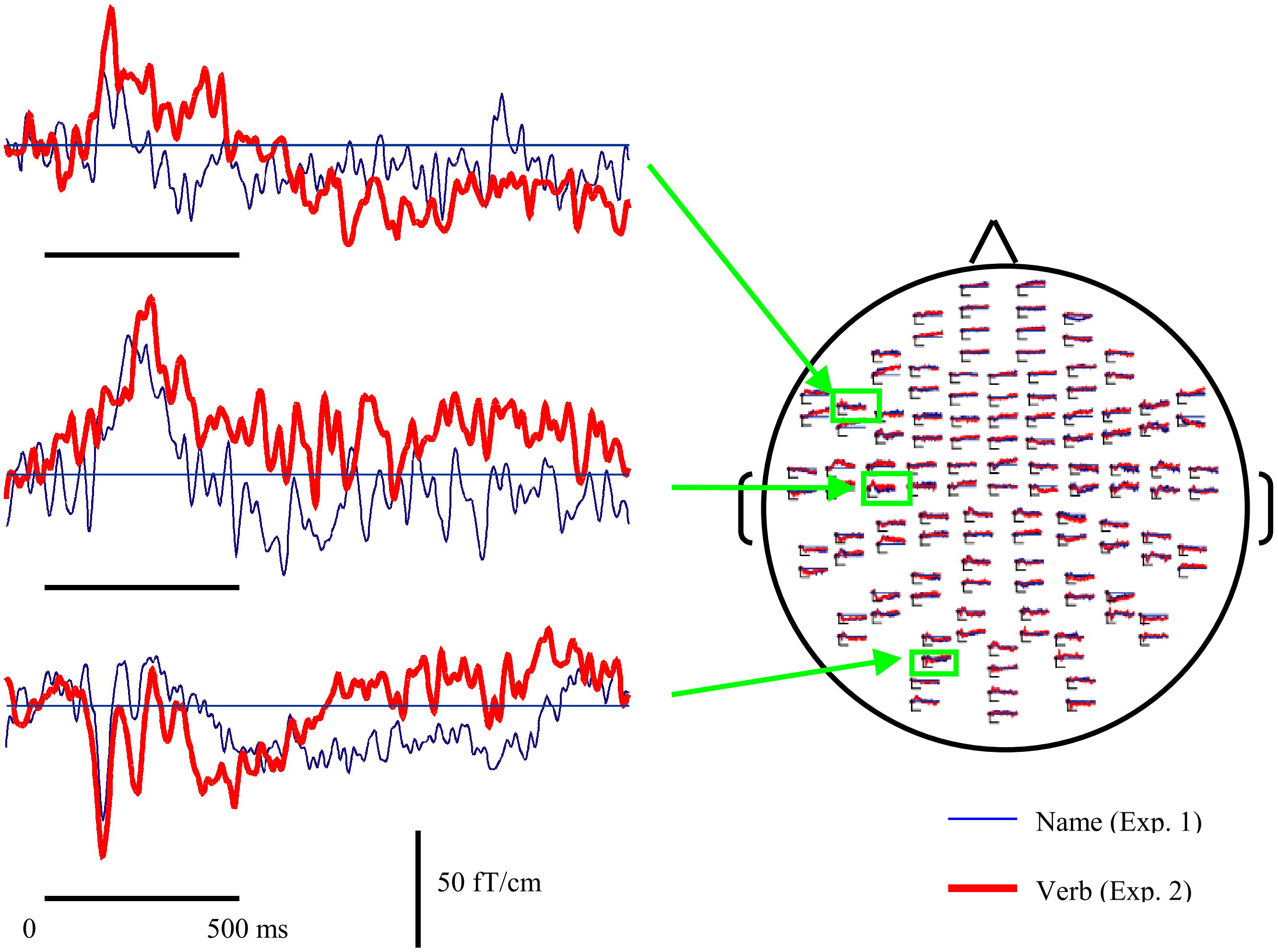

Figure 2: *Response waveforms from 122 channels [subject 1]. Thick lines indicate the responses to English names in Experiment 1. Thin lines indicate the responses to English verb words in Experiment 2.*

3 Results

We obtained the following significantly activated areas; the bilateral occipitotemporal areas, the areas surrounding the bilateral intraparietal sulci, the bilateral occipitoparietal areas, the bilateral supramarginal regions, the left superior parietal lobule, the left superior temporal cortex, and the left inferior insula. The activity was significantly longer in the inferior insula in the left than the right hemisphere. No hemispheric dominance was observed in the other brain regions.

Table 1: *The number of subjects who showed activity in those areas which were significantly activated mainly in Experiment 2.*

	Left	Right
occipitotemporal region	6*	7*
occipitoparietal region	7*	6**
intraparietal sulcus	5*	6*
superior parietal lobule	5*	3
supramarginal region	5*	5*
angular region	2	2
lateral sulcus floor	3	1
superior temporal cortex	5*	4
inferior insula	6*	2
superior insula	1	1

* $p < 0.05$, ** $p < 0.01$

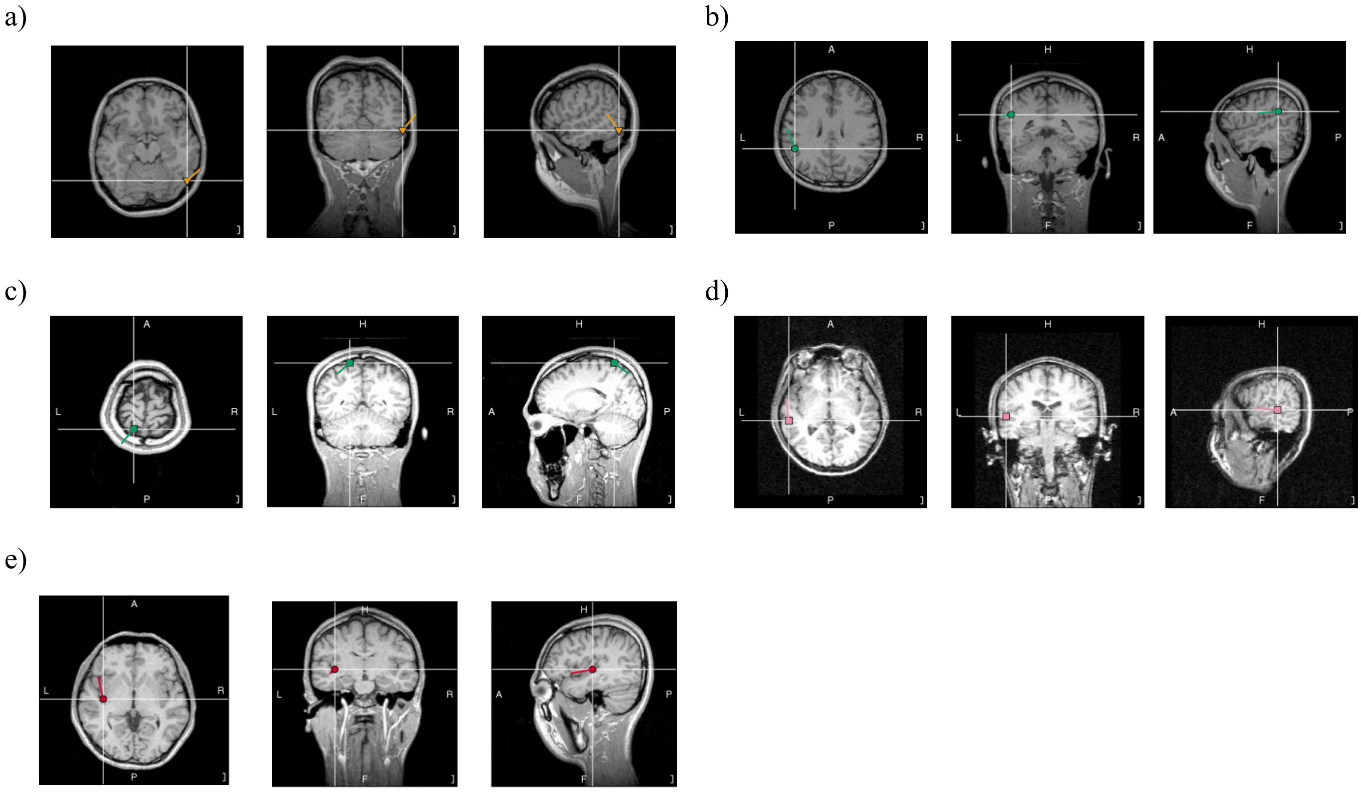

Figure 3: *Typical active regions. a) right occipitotemporal region [subject 6], b) left supramarginal region [subject 1], c) left superior parietal lobule [subject 1], d) left superior temporal cortex [subject 3], e) left inferior insula [subject 1].*

4 Discussion

The regions activated mainly in Experiment 2, which seem to be related to the translation activity, were the bilateral occipitotemporal areas, the areas surrounding the bilateral intraparietal sulci, the bilateral occipitoparietal areas, the bilateral supramarginal regions, the left superior parietal lobule, the left superior temporal cortex, and the left inferior insula.

We assumed that the task in Experiment 1 included the processes related to detecting the word, reading the word, and speaking the English name whereas that in Experiment 2 included detecting the word, reading the word, understanding the meaning, retrieving the Japanese word of the same meaning, and speaking the Japanese word. We also assumed that the subtraction of the ECD clusters obtained in Experiment 1 from those obtained in Experiment 2 showed the ECD clusters related to the activity necessary mainly in Experiment 2. Therefore, the resulted ECD clusters imply the regions activated by "understanding the meaning" and "retrieving the Japanese word of the same meaning." These processes are essential to the translation, and thus we suggest that the above areas are related to translation activity.

We employed the imperative stimulus to avoid the contamination from the motor activity or readiness activity related to utterance. We did not find a significant activity in these motor related areas during the analysis time from –0.1 s to 1.5 s, and thus the imperative stimulus effectively suppressed the motor activity during the analysis time. However, someone may claim that the subject may keep the stimulus itself in mind and perform the translation immediately after the imperative stimulus, resulting in no translation activity during our analysis time. This may happen when the visual stimulus is presented very briefly and when the cost to keep the visual stimulus itself in mind is lower than to do task work immediately. In our case, however, the visual stimulus was presented for 1.0 seconds which was long enough for the subject to perform the translation, and moreover, keeping the Japanese word (translation result) in mind is much easier for the Japanese subjects than keeping the English word in mind. Therefore, we believe that the translation was performed during the analysis time. This is supported by the subject's report after the experiment.

Price et al. [1] showed in their Positron Emission Tomography study that the activity increased in the anterior cingulate, the anterior insula, the cerebellum, the supplementary motor area, and the subcortical structures. In their study, the subject spoke the word silently by moving the mouth, which may activate the motor- or speaking-related areas, which are the anterior insula, the cerebellum, the supplementary motor area, and the subcortical structures. The rest of the regions they found active are the anterior cingulate, where we did not find significant activity in our result. In their study, strangely the activity decreased in the temporal and parietal language areas. The differences between their results and our results may be explained by the stimulus, the task, and the language experience of the subjects. However, the differences should be clarified by further studies.

References

1. C. Price, D. Green and R. Studnitz, “A functional imaging study of translation and language switching”, *Brain* **122**, 2221-2235, 1999
2. T. Imada, T. Mashiko, and H. Sekine, "Estimation errors of single dipole model applied to twin dipole activity", this volume.